



Guaranteed Quality and Expertise In Civil Engineering Review

MEGAREVIEW and Tutorial Center

MANILA - CEBU - BAGUIO - DAVAO



MANILA BRANCH
2nd Floor, JPD Building, 1955 C. M.
Recto Avenue, Sampaloc, Metro Manila

BAGUIO BRANCH
UGF-09, Upper Ground Floor, Pilando
Center, Magsaysay Avenue, Baguio City

CEBU BRANCH
4th Floor, J. Martinez Building, Jones
Avenue, Osmeña Boulevard, Cebu City

DAVAO BRANCH
3rd Floor, FTC Tower, 1034 Mount Apo
Street, Poblacion District, Davao City

FOR MANILA AND BAGUIO BRANCH, CONTACT HERE:
09195832155 (SMART)
09562568509 (GLOBE)

FOR CEBU AND DAVAO BRANCH, CONTACT HERE:
09084507496 (SMART)
09151986630 (GLOBE)

REVIEW MODULE: TRANSPORTATION ENGINEERING

FUNDAMENTALS OF TRAFFIC FLOW

Speed (μ) – distance traveled per unit of time.

Time Mean Speed (v_t) – arithmetic mean of the speeds observed at some designated point along the roadway.

Space Mean Speed (v_s) – harmonic mean of the speeds observed at some designated point along the roadway.

1. Traffic engineers placed sensors along a 1.5-km downhill segment of an expressway to study how slope affects vehicle speeds. Five vehicles were tracked, and instead of recording the travel time for the entire segment, the sensors captured their average speeds along the segment. Determine the Time Mean Speed and Space Mean Speed. (84.6, 84.3)

Vehicles	Speed (kph)
1	85
2	78
3	92
4	88
5	80

SPEED, DENSITY AND FLOW RELATIONSHIP

Traffic Flow (q) – the rate at which vehicles pass a given point in a roadway given in terms of vehicles per unit of time.

Traffic Density (k) – measure of the number of vehicles occupying a length of roadway.

Space Headway – the distance between successive vehicles moving in the same lane measured from head-to-head at any instance.

Time Headway – the time interval between the passage of successive vehicles moving in the same lane measured from head-to-head as they pass a point on the road.

Relationship between **traffic flow**, **space mean speed** and **density**.
$$q = v_s k$$

SITUATION | A drone records 20 vehicles on a 1.2-km stretch of a section of a highway. Average time headway is 6sec.

2. Determine the density in vehicles / km. (16.67)
3. Determine the traffic flow in vehicles/hr. (600)
4. Determine the space mean speed. (36kph)

SITUATION | On a coastal highway, a detector station monitors vehicles passing through a single lane. The average vehicle time headway is recorded as 3.2 seconds per vehicle. A drone flying above the same segment measures the average spacing between vehicles as 42 meters.

5. Compute the traffic density.
6. Determine the space mean speed in kph.

JAM DENSITY AND FREE FLOW SPEED

Jam Density (k_j) – the density at which the speed of traffic is approaching zero.

Free Flow Speed (v_f) – the speed at which the density of traffic is approaching

Capacity/Maximum Flow (q_{max}) – ability of a roadway to accommodate traffic. Maximum number of vehicles that can pass a given point in unit time.

$$q_{max} = v_{opt} k_{opt} = \left(\frac{v_f}{2}\right) \left(\frac{k_j}{2}\right) = \frac{v_f k_j}{4}$$

SITUATION | A city is evaluating traffic performance on a 6 km stretch of an arterial road. To model traffic behavior, engineers conducted a study under two different traffic conditions. For the first traffic condition (light traffic), the road has a density of 20veh/km with an average speed of 90kph. For the second condition (heavy traffic), the density is 180veh/km with average speed of 10kph.

7. Determine the free flow speed in kph. (100)
8. Determine the jam density in veh/km. (200)
9. Determine the maximum flow of the traffic stream in veh/hr. (5000)

QUEUING THEORY

Queue – vehicles/individuals lining up and waiting for service.

Arrival Rate (λ) – the rate at which vehicles arrive at the queue point.

Departure Rate (μ) – rate at which vehicles leave the queue point.

Traffic Intensity (ρ) – ratio of arrival rate and departure rate.

D/D/1 QUEUING

This queuing model is the simplest having deterministic arrivals, deterministic departure and one departure channel.

SITUATION | The Northern Luzon Expressway is designed to have a roadway capacity of 120 vehicles per minute. But due to road accident on the expressway, the road capacity was reduced to 60 vehicles per minute. The traffic arrivals are 80 vehicles per minute. The traffic then resumes after 30minutes.

10. In how many minutes will the queue dissipate?
11. Determine the length of queue 20 mins after the accident.
12. Determine the maximum length of queue if the average length of one car is 3.5m.
13. How many vehicles were affected by the accident?
14. Compute the total delay and the average delay per vehicle.

SERVICE RATES AND DEMAND ON HIGHWAYS

SERVICE RATE – associated with departure rate (μ); describes the number of vehicles given service on a highway.

DEMAND – associated with arrival rate (λ); describes the number of vehicles arriving at the queue point and awaiting service.

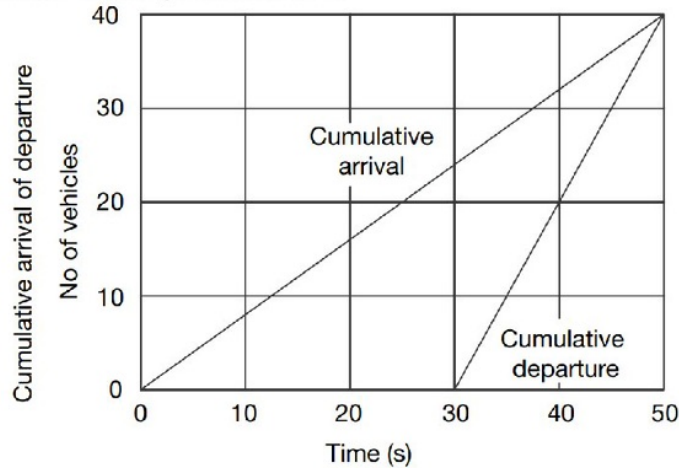
QUEUE (Q) – difference between the Demand and Service Rate for a certain stretch of a highway.

SITUATION | A ramp meter operates during the morning peak period. Ramp meter cycles vary with time as shown in the table below. The metering scheme allows one vehicle per cycle to pass the signal. The table below gives the number of vehicles demanding service on the ramp during the particular time intervals, the cumulative demand for the ramp for the morning peak and the ramp meter cycle for each interval.

Time Period	15 Min Volume	Cumulative Volume	Meter Cycle (S)
6:30 – 6:45	75	75	6
6:45 – 7:00	100	175	10
7:00 – 7:15	125	300	12
7:15 – 7:30	110	410	12
7:30 – 7:45	80	490	10
7:45 – 8:00	65	555	6

15. Compute the service rate for Meter Cycle 6, 10 and 12.
16. Determine when the queue on the ramp begins and ends.
17. Determine the longest queue in vehicles.

SITUATION | The cumulative arrival and departure curve of one cycle of an approach lane of a signalized intersection is shown in the adjoining figure. The cycle time is 50s and the effective red time is 30s and the effective green time is 20 s.



18. What is the total delay?
19. What is the average delay?

SITUATION | A toll bridge carries 5000 veh/day. The current toll is ₱150.00. When the toll is increased by ₱25.00, traffic volume decreases by 500 veh/day.

20. Write an expression for travel demand on the bridge related to toll increase and current volume.
21. Determine the amount of toll that should be charged such that revenue is maximized.
22. How much additional revenue will be received?

PEAK HOUR FACTOR

$$\text{Peak Hour Factor (PHF)} = \frac{PHV}{\text{Highest Period Volume}}$$

The Peak Hour Factor (PHF) measures how steady traffic flows during peak hour.

SITUATION | For the given data shown:

TIME	VOLUME
7:00 – 7:15	37
7:15 – 7:30	27
7:30 – 7:45	29
7:45 – 8:00	28
8:00 – 8:15	34
8:15 – 8:30	35

23. Peak hour & Peak hour volume.
24. Peak hour factor.
25. Design Hourly Volume.
26. The maximum value of 15-minute peak hour factor on a section of a road is _____.
27. The minimum value of 15-minute peak hour factor on a section of a road is _____.

ACCIDENT ANALYSIS

Directional Design Hourly Volume:

$$DDHV = k(D)(AADT)$$

k = proportion of AADT occurring at the peak hour

D = peak hour volume proportion in the major direction

Accident rate per million entering vehicles (MEV) for an INTERSECTION:

$$R = \frac{A(1\,000\,000)}{ADT(N)(365)}$$

Accident rate for 100 million vehicle miles of travel (HMVM) for a SEGMENT OF A HIGHWAY:

$$R = \frac{A(100\,000\,000)}{ADT(N)(365L)}$$

Severity Ratio

$$SR = \frac{\text{fatal} + \text{injury accidents}}{\text{fatal} + \text{injury accidents} + \text{property damage}}$$

28. The projected AADT of a proposed facility is 33,000 veh/day. If the proportion of AADT in the design hour is 16 percent and the peak-hour directional distribution is 65:35. Determine the DDHV.
29. A local jurisdiction has determined that for a given set of geometric conditions, a maximum rate of 8 crashes/million entering vehicles can be tolerated. At an intersection of 2 roadways with ADTs of 10,000 and 7500, how many crashes can occur before corrective action must be sought?
30. The number of accidents for 5 years recorded in a 10 – mile long highway is 2345. If the average daily traffic is 397, what is the accident rate per hundred million vehicle miles of travel?
31. Data on a traffic accident recorded for the past 3 years on a certain stretch of a two-lane highway in TPLEX is tabulated as follows. Determine the severity ratio for the given accident record.

Year	Property Damage	Injury	Fatal
2023	121	84	6
2024	149	31	7
2025	271	47	16

ADDITIONAL TOPICS:

M/D/1 QUEUEING

Queueing that has exponentially distributed arrivals, deterministic departures and one departure channel.

Average Length of Queue _____ $\bar{Q} = \frac{\rho^2}{2(1-\rho)}$
Average Waiting Time in Queue _____ $\bar{W} = \frac{\rho}{2\mu(1-\rho)}$
Average Time Spent in the System _____ $\bar{t} = \frac{2-\rho}{2\mu(1-\rho)}$

32. Vehicles arrive at the parking entrance of the new SM. There is a single toll booth at which all vehicles must stop and pay parking fee. It takes the attendant 15 seconds to distribute the parking ticket to every vehicle. The average arrival rate of vehicles is 200 veh/h and it is unevenly distributed (Assume that the arrival rate follow Poisson's distribution) over the entire period.
a. Determine the Average length of queue
b. Average Waiting time in queue
c. Average time spent in system.

M/M/1 QUEUEING

Queueing that has exponentially distributed arrivals, exponentially distributed departures and one departure channel.

Average Length of Queue _____ $\bar{Q} = \frac{\rho^2}{1-\rho}$
Average Waiting Time in Queue _____ $\bar{W} = \frac{\lambda}{\mu(\mu-\lambda)}$
Average Time Spent in the System _____ $\bar{t} = \frac{1}{\mu-\lambda}$

33. Assume that the toll attendant in the new toll gate takes an average of 4 minutes to serve each vehicle, but the distribution time varies depending on whether drivers pay exact toll fee. Given an average arrival rate of 12 veh/h which vehicles arrive at unequal time intervals.
a. Determine the Average length of queue
b. Average Waiting time in queue
c. Average time spent in system.

Solution of Additional Problems:



FUNDAMENTALS OF TRAFFIC FLOW

Speed (μ) – distance traveled per unit of time.
Time Mean Speed (v_k) – **arithmetic mean** of the speeds observed at some designated point along the roadway.
Space Mean Speed (v_s) – **harmonic mean** of the speeds observed at some designated point along the roadway.

1. Traffic engineers placed sensors along a 1.5-km downhill segment of an expressway to study how slope affects vehicle speeds. Five vehicles were tracked, and instead of recording the travel time for the entire segment, the sensors captured their average speeds along the segment. Determine the Time Mean Speed and Space Mean Speed. (84.6, 84.3)

Vehicles	Speed (kph)
1	85
2	78
3	92
4	88
5	80

TIME MEAN SPEED (TMS) • $t = \frac{d}{v}$

• $TMS = \frac{v_1 + v_2 + v_3 + v_4 + v_5}{n}$
 $TMS = \frac{85 + 78 + 92 + 88 + 80}{5}$
 $TMS = 84.6 \text{ kph}$

TMS = 84.6 kph

SPACE MEAN SPEED (SMS)

• $t = \frac{d}{v}$
• $t_{AVE} = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{n}$
• $SMS = \frac{d}{t_{AVE}}$ NOTE : SMS IS THE HARMONIC MEAN
 $SMS = \frac{85 + 78 + 92 + 88 + 80}{5}$
 $SMS = 84.3 \text{ kph}$
ALWAYS LESS THAN TMS (84.6 kph) ✓

SMS = 84.3 kph

SPEED, DENSITY, AND FLOW RELATIONSHIP

Traffic Flow (q) – the rate at which vehicles pass a given point in a roadway given in terms of vehicles per unit of time.

$$q = \frac{N}{t}$$

Traffic Density (k) – measure of the number of vehicles occupying a length of roadway.

$$k = \frac{N}{L}$$

Space Headway – the distance between successive vehicles moving in the same lane measured from head-to-head at any instance.

Time Headway – the time interval between the passage of successive vehicles moving in the same lane measured from head-to-head as they pass a point on the road.

Relationship between traffic flow, space mean speed and density.

$$q = v_s k$$

SITUATION | A drone records 20 vehicles on a 1.2-km stretch of a section of a highway. Average time headway is 6sec.

2. Determine the density in vehicles / km. (16.67)

$$\begin{aligned} k &= \frac{N}{L} = \frac{20 \text{ VEH}}{1.2 \text{ km}} \\ k &= 16.67 \text{ VEH/km} \\ k &= 17 \text{ VEH/km} \quad \# \end{aligned}$$

$$k = 16.67 \text{ VEH/km}$$

3. Determine the traffic flow in vehicles/hr. (600)

$$\begin{aligned} q &= \frac{N}{t} = \frac{1 \text{ VEH}}{6 \text{ sec}} \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right) \\ q &= 600 \text{ VEH/hr} \quad \# \end{aligned}$$

$$q = 600 \text{ VEH/hr}$$

4. Determine the space mean speed. (36kph)

$$\begin{aligned} q &= v_s k \\ (600) &= v_s (16.667) \\ v_s &= 36 \text{ kph} \quad \# \end{aligned}$$

$$v_s = 36 \text{ kph}$$

SITUATION | On a coastal highway, a detector station monitors vehicles passing through a single lane. The average vehicle time headway is recorded as 3.2 seconds per vehicle. A drone flying above the same segment measures the average spacing between vehicles as 42 meters.

5. Compute the traffic density.

$$\begin{aligned} h_T &= 3.2 \text{ sec/VEH} \\ h_s &= 42 \text{ m/VEH} \\ k &= \frac{N}{L} = \frac{1 \text{ VEH}}{42 \text{ m} \left(\frac{1 \text{ km}}{1000 \text{ m}} \right)} \\ k &= 23.81 \text{ VEH/km} \quad \# \end{aligned}$$

$$k = 23.81 \text{ VEH/km}$$

6. Determine the space mean speed in kph.

$$\begin{aligned} q &= \frac{N}{t} = \frac{1 \text{ VEH}}{3.2 \text{ sec}} \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right) \\ q &= 1125 \text{ VEH/hr} \quad \# \\ q &= v_s k \\ (1125) &= v_s (23.81) \\ v_s &= 47.25 \text{ kph} \quad \# \end{aligned}$$

$$v_s = 47.25 \text{ kph}$$

JAM DENSITY AND FREE FLOW SPEED

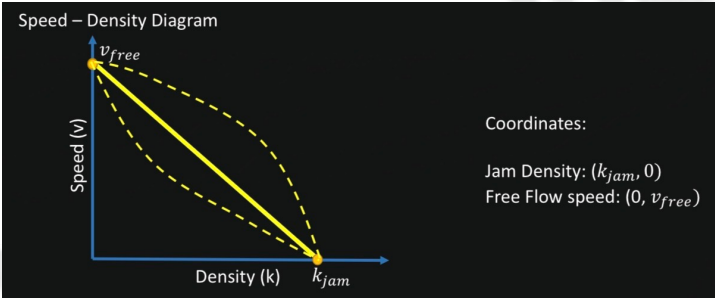
Jam Density (k_j) – the density at which the speed of traffic is approaching zero.
Free Flow Speed (v_f) – the speed at which the density of traffic is approaching
Capacity/Maximum Flow (q_{max}) – ability of a roadway to accommodate traffic. Maximum number of vehicles that can pass a given point in unit time.

$$q_{max} = v_{opt}k_{opt} = \left(\frac{v_f}{2}\right)\left(\frac{k_j}{2}\right) = \frac{v_fk_j}{4}$$

Characteristics of flow, speed and density relationship:

- When the density is zero, flow will also be zero since there is no vehicles on the road.
- When the number of vehicles gradually increases, the density as well as the flow increases.
- When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as the jam density or the maximum density. At jam density, flow will be zero because the vehicles are not moving.

SPEED – DENSITY DIAGRAM



Let $v = y$ – axis
Let $k = x$ – axis

Substitute the given points

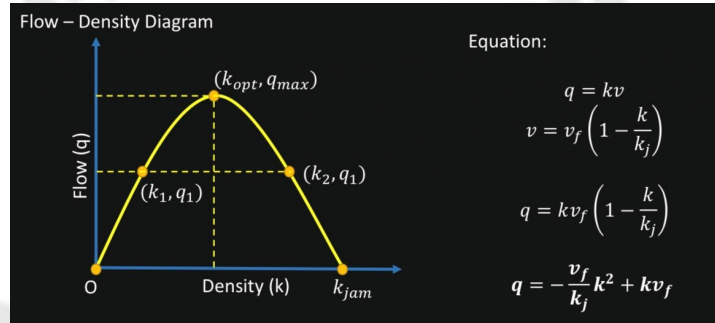
($0, v_{free}$)

$$v = -\frac{v_f}{k_j}(k) + v_f$$

($k_{jam}, 0$)

$$0 = m(k_{jam}) + v_{free}$$
$$m = \frac{-v_{free}}{k_{jam}}$$

FLOW – DENSITY DIAGRAM



$$q = -\frac{v_f}{k_j}k^2 + kv_f$$

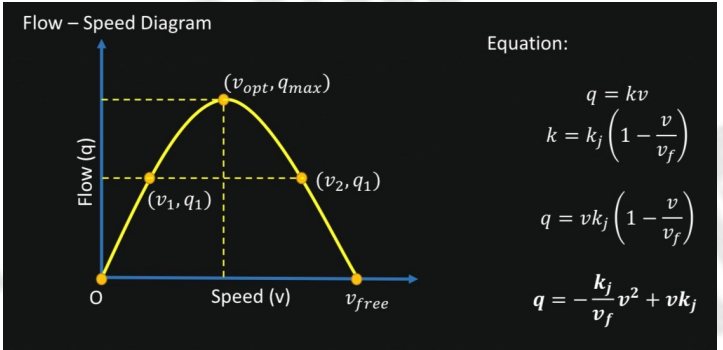
Differentiate with respect to k

$$\frac{dq}{dk} = -\frac{v_f}{k_j}(2k) + v_f$$

Set the derivative to zero

$$\frac{dq}{dk} = 0$$
$$0 = -\frac{v_f}{k_j}(2k) + v_f$$
$$k_{opt} = \frac{k_j}{2}$$

FLOW – SPEED DIAGRAM



$$q = -\frac{k_j}{v_f}v^2 + vk_j$$

Differentiate with respect to v

$$\frac{dq}{dv} = -\frac{k_j}{v_f}(2v) + k_j$$

Set the derivative to zero

$$\frac{dq}{dv} = 0$$
$$0 = -\frac{k_j}{v_f}(2v) + k_j$$
$$v_{opt} = \frac{v_f}{2}$$

$q = kv$
 $q_{max} = k_{opt}v_{opt}$

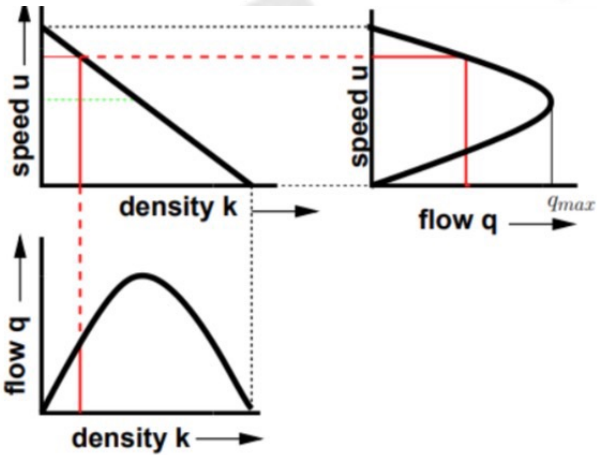


Figure 31:6: Fundamental diagram of traffic flow

SITUATION | A city is evaluating traffic performance on a 6 km stretch of an arterial road. To model traffic behavior, engineers conducted a study under two different traffic conditions. For the first traffic condition (light traffic), the road has a density of 20veh/km with an average speed of 90kph. For the second condition (heavy traffic), the density is 180veh/km with average speed of 10kph.

7. Determine the free flow speed in kph. (100)

LIGHT TRAFFIC

• $k_1 = 20 \text{ VEH/km}$

• $V_1 = 90 \text{ kph}$

• $q_1 = (20)(90)$

$q_1 = 1800 \text{ VEH/HR}$ //

HEAVY TRAFFIC

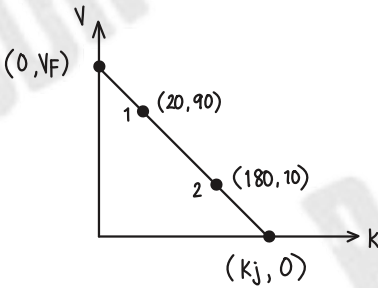
• $k_2 = 180 \text{ VEH/km}$

• $V_2 = 10 \text{ kph}$

• $q_2 = (180)(10)$

$q_2 = 1800 \text{ VEH/HR}$ //

SPEED – DENSITY DIAGRAM



MODE – STAT – LINEAR

X	Y
20	90
180	10

• FREE FLOW = ZERO DENSITY

FREE FLOW = $0 \hat{y} = 100 \text{ kph}$ //

$V_F = 100 \text{ kph}$

8. Determine the jam density in veh/km. (200)

• JAM DENSITY = ZERO SPEED (NOT MOVING)

JAM DENSITY = $0 \hat{x} = 200 \text{ VEH/km}$ //

$K_j = 200 \text{ VEH/km}$

9. Determine the maximum flow of the traffic stream in veh/hr. (5000)

• $q_{MAX} = \frac{V_F K_j}{4} = \frac{200 (100)}{4}$

$q_{MAX} = 5000 \text{ VEH/hr}$ //

$q_{MAX} = 5000 \text{ VEH/hr}$

QUEUEING THEORY

Queue – vehicles/individuals lining up and waiting for service.

Arrival Rate (λ) – the rate at which vehicles arrive at the queue point.

Departure Rate (μ) – rate at which vehicles leave the queue point.

Traffic Intensity (ρ) – ratio of arrival rate and departure rate.

D/D/1 QUEUEING

This queueing model is the simplest having deterministic arrivals, deterministic departure and one departure channel.

SITUATION | The Northern Luzon Expressway is designed to have a roadway capacity of 120 vehicles per minute. But due to road accident on the expressway, the road capacity was reduced to 60 vehicles per minute. The traffic arrivals are 80 vehicles per minute. The traffic then resumes after 30 minutes.

10. In how many minutes will the queue dissipate?

- $\lambda = 80 \text{ VEH/min}$
- $\mu_1 = 60 \text{ VEH/min}$ ($0 \leq t \leq 30$) DURING THE ACCIDENT
- $\mu_2 = 120 \text{ VEH/min}$ ($t > 30$) TRAFFIC RESUMES BACK AFTER 30 MINUTES, IT IS BACK TO ITS ORIGINAL CAPACITY

QUEUE = 0 (DISSIPATE)

- NO. OF ARRIVAL = NO. OF DEPARTURE
- $80t = 60(30) + 120(t - 30)$
- $t = 45 \text{ MINS}$ //

$$t = 45 \text{ MINS}$$

11. Determine the length of queue 20 mins after the accident.

- $Q_{20} = \text{ARRIVAL} - \text{DEPARTURE}$
- $Q_{20} = 80(20) - 60(20)$
- $Q_{20} = 400 \text{ VEH}$ //

$$Q_{20} = 400 \text{ VEH}$$

12. Determine the maximum length of queue if the average length of one car is 3.5m.

- Q_{MAX} AT 30 MINS
- $Q_{\text{MAX}} = \text{ARRIVAL} - \text{DEPARTURE}$
- $Q_{\text{MAX}} = 80(30) - 60(30)$
- $Q_{\text{MAX}} = 600 \text{ VEH} \times 3.5\text{m}$
- $Q_{\text{MAX}} = 2100\text{m}$ //

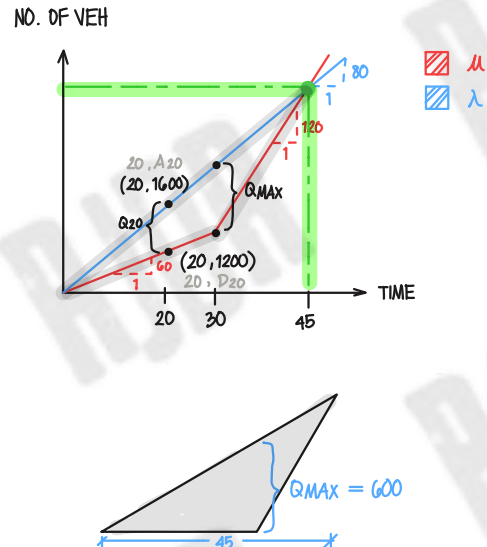
$$Q_{\text{MAX}} = 2100\text{m}$$

13. How many vehicles were affected by the accident?

- $N = 80 \text{ VEH/min} (45 \text{ mins})$
- $N = 3600 \text{ VEH}$ //

$$N = 3600 \text{ VEH}$$

14. Compute the total delay and the average delay per vehicle.



TIME-DELAY = AREA

- $A = \frac{1}{2}(45)(600)$
- $A = 13500 \text{ VEH-MIN}$

AVERAGE-DELAY

- $AD = \frac{TD}{N} = \frac{13500 \text{ VEH-MIN} \left(\frac{60\text{s}}{1\text{min}}\right)}{3600}$
- $AD = 225 \text{ seconds}$
- $AD = 3.75 \text{ MINS}$ //

$$AD = 3.75 \text{ MINS}$$

SERVICE RATES AND DEMAND ON HIGHWAYS

SERVICE RATE – associated with departure rate (μ); describes the number of vehicles given service on a highway.
DEMAND – associated with arrival rate (λ); describes the number of vehicles arriving at the queue point and awaiting service.
QUEUE (Q) – difference between the Demand and Service Rate for a certain stretch of a highway.

SITUATION | A ramp meter operates during the morning peak period. Ramp meter cycles vary with time as shown in the table below. The metering scheme allows one vehicle per cycle to pass the signal. The table below gives the number of vehicles demanding service on the ramp during the particular time intervals, the cumulative demand for the ramp for the morning peak and the ramp meter cycle for each interval.

Time Period	15 Min Volume	Cumulative Volume	Meter Cycle (S)
6:30 – 6:45	75	75	6
6:45 – 7:00	100	175	10
7:00 – 7:15	125	300	12
7:15 – 7:30	110	410	12
7:30 – 7:45	80	490	10
7:45 – 8:00	65	555	6

15. Compute the service rate for Meter Cycle 6, 10 and 12.

SERVICE RATE (SR)

- $SR = \frac{\text{PERIOD}}{\text{METER CYCLE}}$
- $SR_6 = \frac{15 \text{ mins } (\frac{60 \text{ sec}}{1 \text{ min}})}{6 \frac{\text{sec}}{\text{VEH}}} = 150 \text{ VEH} //$
- $SR_{10} = \frac{15 \text{ mins } (\frac{60 \text{ sec}}{1 \text{ min}})}{10 \frac{\text{sec}}{\text{VEH}}} = 90 \text{ VEH} //$
- $SR_{12} = \frac{15 \text{ mins } (\frac{60 \text{ sec}}{1 \text{ min}})}{12 \frac{\text{sec}}{\text{VEH}}} = 75 \text{ VEH} //$

SR₆ = 150 VEH
SR₁₀ = 90 VEH
SR₁₂ = 75 VEH

16. Determine when the queue on the ramp begins and ends.

Time Period	15 Min Volume	Cumulative Volume	Meter Cycle (S)	15 MIN. SERVICE RATE	CUMULATIVE S.R.	DEMAND - S.R.
6:30 – 6:45	75	75	6	150 (+)	75	0
6:45 – 7:00	100	175	10	90 (+)	165	10
7:00 – 7:15	125	300	12	75 (+)	240	60
7:15 – 7:30	110	410	12	75 (+)	315	95
7:30 – 7:45	80	490	10	90 (+)	405	85
7:45 – 8:00	65	555	6	150	555	0

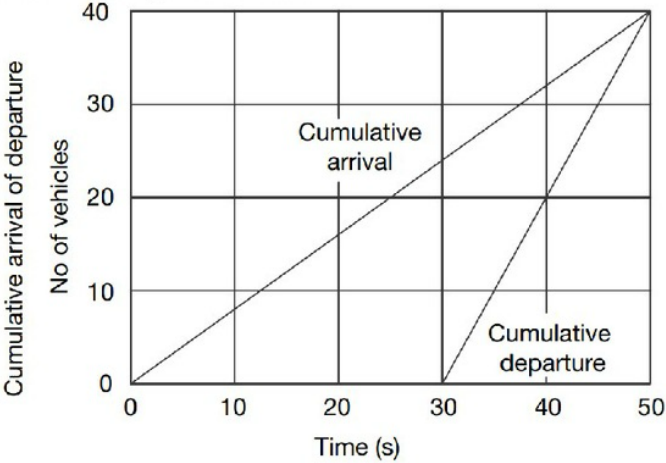
QUEUE STARTED AT 6:45
QUEUE ENDED AT 8:00

17. Determine the longest queue in vehicles.

$Q_{MAX} = 95 \text{ VEH} //$ (FROM DEMAND - S.R.)

Q_{MAX} = 95 VEH

SITUATION | The cumulative arrival and departure curve of one cycle of an approach lane of a signalized intersection is shown in the adjoining figure. The cycle time is 50s and the effective red time is 30s and the effective green time is 20 s.



18. What is the total delay?

$\bullet \text{ TOTAL DELAY} = \frac{1}{2}bh$
 $\text{TOTAL DELAY} = \frac{1}{2} (30s)(40 \text{ VEH})$
 $\text{TOTAL DELAY} = 600 \text{ VEH} - \text{S} //$

TD = 600 VEH - S

19. What is the average delay?

$\bullet \text{ AVERAGE DELAY} = \frac{\text{T.D.}}{\text{NO. OF AFFECTED}}$
 $\text{AVERAGE DELAY} = \frac{600 \text{ VEH} - \text{S}}{40 \text{ VEH}}$
 $\text{AVERAGE DELAY} = 15 \text{ SECONDS} //$

AD = 15s

SITUATION | A toll bridge carries 5000 veh/day. The current toll is ₱150.00. When the toll is increased by ₱25.00, traffic volume decreases by 500 veh/day.

20. Write an expression for travel demand on the bridge related to toll increase and current volume.

CURRENTLY	CHANGES	FIND
$V = 5000$	$\uparrow 25$	V
$T = 150$	$\downarrow 500$	

$$V = 5000 - 500\left(\frac{x}{25}\right) \quad \text{LET } x = \text{TOLL INCREASE}$$

$$V = 5000 - 20x \quad //$$

$$\boxed{V = 5000 - 20x}$$

21. Determine the amount of toll that should be charged such that revenue is maximized.

$$\begin{aligned} \textcircled{1} \quad R &= VT \\ R &= (5000 - 20x)(150 + x) \\ R &= 750,000 + 5000x - 3000x - 20x^2 \\ R &= 750,000 + 2000x - 20x^2 \end{aligned}$$

$$\textcircled{2} \quad \frac{dR}{dx} = 2000 - 40x$$

$$\begin{aligned} \textcircled{3} \quad 0 &= 2000 - 40x \\ x &= 50 \quad // \end{aligned}$$

$$\begin{aligned} \bullet \quad T &= 150 + x \\ T &= 150 + 50 \\ T &= 200 \quad // \end{aligned}$$

$$\boxed{\text{TOLL} = 200}$$

22. How much additional revenue will be received?

$$\begin{aligned} \bullet \quad R_{ADD} &= R_F - R_I \\ R_{ADD} &= [5000 - 20(50)](200) - 5000(150) \\ R_{ADD} &= 50,000 \quad // \end{aligned}$$

$$\boxed{R_{ADD} = 50,000.00 \text{ PHP}}$$

PEAK HOUR FACTOR

$$\text{Peak Hour Factor (PHF)} = \frac{PHV}{\text{Highest Period Volume}}$$

The Peak Hour Factor (PHF) measures how steady traffic flows during peak hour.

SITUATION | For the given data shown:

TIME	VOLUME
7:00 – 7:15	37
7:15 – 7:30	27
7:30 – 7:45	29
7:45 – 8:00	28
8:00 – 8:15	34
8:15 – 8:30	35

$7:00 - 8:00 \rightarrow 121$
 $7:15 - 8:15 \rightarrow 118$
 $7:30 - 8:30 \rightarrow 126$

23. Peak hour & Peak hour volume.

- PEAK HOUR : 7:30 – 8:30
- PEAK HOUR VOLUME : 35
LARGEST VOLUME WITHIN PEAK VOLUME

$$7:30 - 8:30 : 35$$

24. Peak hour factor.

$$\begin{aligned} \text{PHF} &= \frac{PHV}{4V_{15}} = \frac{126}{4(35)} \\ \text{PHF} &= 0.9 \end{aligned}$$

$$\text{PHF} = 0.9$$

25. Design Hourly Volume.

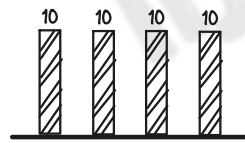
$$\begin{aligned} \text{DHV} &= 4V_{15} \\ \text{PHF} &= \frac{PHV}{4V_{15}} ; 4V_{15} = \frac{PHV}{\text{PHF}} \\ \text{DHV} &= \frac{PHV}{\text{PHF}} \\ \text{PHF} &= \frac{PHV}{\text{DHV}} \end{aligned}$$

$$\begin{aligned} \text{DHV} &= 4V_{15} \\ \text{DHV} &= 4(35) \\ \text{DHV} &= 140 \text{ VEH} \end{aligned}$$

$$\text{DHV} = 140 \text{ VEH}$$

26. The maximum value of 15-minute peak hour factor on a section of a road is _____.

(IN GENERAL) : ASSUMING VALUES ARE UNIFORM

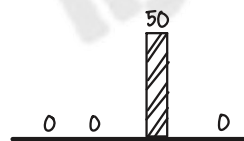


$$\text{PHF} = \frac{40}{4(10)} = 1 \quad \text{ALWAYS}$$

$$\text{PHF}_{\text{MAX}} = 1$$

27. The minimum value of 15-minute peak hour factor on a section of a road is _____.

(IN GENERAL) : ASSUMING VALUES ARE ZERO AND 1 MAXIMUM



$$\text{PHF} = \frac{50}{4(50)} = 0.25 \quad \text{FOR 15 MIN.}$$

ASSUMING INTERVAL IS 15mins, 15min x 4 = 1hr

$$\text{PHF}_{\text{MIN}} = 1/4$$

ACCIDENT ANALYSIS

Directional Design Hourly Volume:

DDHV = k(D)(AADT)

k = proportion of AADT occurring at the peak hour

D = peak hour volume proportion in the major direction

Accident rate per million entering vehicles (MEV) for an INTERSECTION:

R = A(1 000 000) / ADT(N)(365)

Accident rate for 100 million vehicle miles of travel (HMVM) for a SEGMENT OF A HIGHWAY:

R = A(100 000 000) / ADT(N)(365L)

Severity Ratio

SR = fatal + injury accidents / fatal + injury accidents + property damage

31. Data on a traffic accident recorded for the past 3 years on a certain stretch of a two-lane highway in TPLEX is tabulated as follows. Determine the severity ratio for the given accident record.

Year	Property Damage	Injury	Fatal
2023	121	84	6
2024	149	31	7
2025	271	47	16

Σ 541 162 29

• SR = (F + I) / (F + I + P.D.)

SR = (29 + 162) / (29 + 162 + 541)

SR = 26%

SR = 26%

28. The projected AADT of a proposed facility is 33,000 veh/day. If the proportion of AADT in the design hour is 16 percent and the peak-hour directional distribution is 65:35. Determine the DDHV.

• DDHV = AADT (k)(D)
DDHV = (33000)(0.16)(65/100) → 65 + 35
DDHV = 3432 VEH/HR //

DDHV = 3432 VEH/HR

29. A local jurisdiction has determined that for a given set of geometric conditions, a maximum rate of 8 crashes/million entering vehicles can be tolerated. At an intersection of 2 roadways with ADTs of 10,000 and 7500, how many crashes can occur before corrective action must be sought?

RATIO AND PROPORTION

• 8 / (1x10^6 VEH) = A / ((10,000 + 7500)(365)(1))
A = 52 //

A = 52

30. The number of accidents for 5 years recorded in a 10 – mile long highway is 2345. If the average daily traffic is 397, what is the accident rate per hundred million vehicle miles of travel?

RATIO AND PROPORTION

• RACCIDENT / (1x10^8 VEH) = 2345 / (397(365x5)(10))
RACCIDENT = 32,367 PER HUNDRED MILLION //

RACCI = 32,367 / 1x10^8

Question No. 5 of 25

It is the clear distance between two consecutive vehicles.

Mark the correct answer from the selection below.

☐ A	time headway	☐ B	space headway
☐ C	gap	☒ D	clearance

CLEARANCE

Question No. 6 of 25

A section of the extension of the NLEX connecting Pampanga and Tarlac is known to have a free flow speed of 50kph and a capacity of 3200 vehicles per hour. In a given hour, 2000 vehicles were counted at a specified point along this highway section. Compute the jam density in veh/km.

Mark the correct answer from the selection below.

☐ A	265	☒ B	256
☐ C	400	☐ D	327

$$q_{CAP} = \frac{K_J V_F}{4}$$
$$3200 = \frac{K_J (50)}{4}$$
$$K_J = 256 \text{ VEH/km}$$

K_J = 256 VEH/km

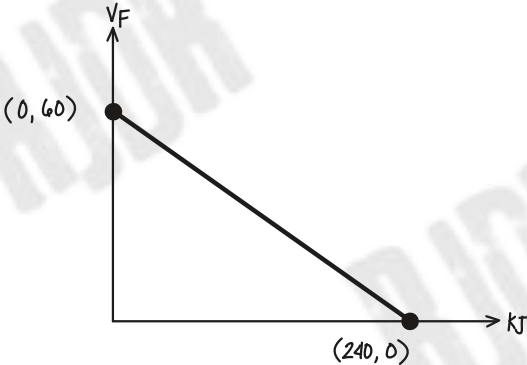
Question No. 7 of 25

A portion of the extension of SLEX has a free flow speed of 60kph and a capacity of 3600 veh/hr. If in a given hour, 3344 vehicles were counted at a specified point along this highway, determine the traffic density (veh/km) of these 3344 vehicles.

Mark the correct answer from the selection below.

☐ A	240	☒ B	88
☐ C	83	☐ D	38

$$q_{CAP} = \frac{K_J V_F}{4}$$
$$3600 = \frac{K_J (60)}{4}$$
$$K_J = 240 \text{ VEH/km}$$



MODE - STAT - LINEAR

X	Y
240	0
0	60

APPS - REG - A → (A)
APPS - REG - B → (B)

$$q = K V$$
$$3344 = K (A + B K)$$
$$K = 88 \text{ VEH/km}$$

K = 88 VEH/km

SITUATION. Five vehicles pass a section A at intervals of 3, 4, 3 and 5 sec. respectively. The vehicles speeds are 50, 45, 40, 35 and 30 kph respectively. Determine the time mean speed in kph.

Mark the correct answer from the selection below.

☒ A	40.0	☐ B	38.72
☐ C	37.62	☐ D	35.77

TIME MEAN SPEED = ARITHMETIC MEAN

$$TMS = \frac{50 + 45 + 40 + 35 + 30}{5}$$
$$TMS = 40$$

TMS = 40

Question No. 2 of 25

SITUATION. Five vehicles pass a section A at intervals of 3, 4, 3 and 5 sec. respectively. The vehicles speeds are 50, 45, 40, 35 and 30 kph respectively. Determine the space mean speed in kph.

Mark the correct answer from the selection below.

☐ A	40.0	☒ B	38.72
☐ C	37.62	☐ D	35.77

SPACE MEAN SPEED = HARMONIC MEAN

$$SMS = \frac{50^{-1} + 45^{-1} + 40^{-1} + 35^{-1} + 30^{-1}}{5}$$
$$SMS = 38.72$$

SMS = 38.72

Question No. 3 of 25

During peak hours, 3800 vehicles pass a certain highway from 9:00AM to 11:00AM with a space mean speed of 20kph. What is the traffic density in vehicles per km?

Mark the correct answer from the selection below.

☐ A	380	☐ B	190
☒ C	95	☐ D	48

TRAFFIC DENSITY

$$K = \frac{N}{L} = \frac{3800 \text{ VEH}}{20 \text{ kph}(2\text{hrs})}$$
$$K = 95 \text{ VEH/km}$$

K = 95 VEH/km

Question No. 4 of 25

Compute the rate of flow in vehicles per hour if the space mean speed is 30mph and the density is 14 veh/km.

Mark the correct answer from the selection below.

☐ A	420	☒ B	676
☐ C	240	☐ D	766

$$q = K V$$
$$q = (48.28)(14)$$
$$q = 675.92 \text{ VEH/hr}$$
$$q = 676 \text{ VEH/hr}$$

q = 676 VEH/hr

Question No. 8 of 25

SITUATION. Vehicles arrive at the entrance of the new extension of NLEX. There is a single tollgate at which all vehicles must stop where a toll attendant distributes a trip ticket. The toll opens at 6AM at which time vehicles begin to arrive at the rate of 8 vehicles per minute. After 20 minutes, the arrival flow rate declines to 2 vehicles per minute and it continues at that level for the remainder of the day. If the time required to distribute the trip ticket is 15 seconds, Determine the time the queue dissipates.

Mark the correct answer from the selection below.

☐ A 6:00 AM

☒ B 7:00 AM

☐ C 8:00 AM

☐ D 9:00 AM

- ARRIVAL RATE $\lambda_1 = 8 \text{ VEH/MIN}$ (FIRST 20 MINS)
- ARRIVAL RATE $\lambda_2 = 2 \text{ VEH/MIN}$
- DEPARTURE RATE $\mu = 15 \text{ sec/VEH}$ OR 4 VEH/MIN
- ARRIVAL = DEPARTURE
 $8(20) + 2(t - 20) = 4t$
 $t = 60 \text{ MINS}$ //

t = 7:00 AM

Question No. 9 of 25

SITUATION. Vehicles arrive at the entrance of the new extension of NLEX. There is a single tollgate at which all vehicles must stop where a toll attendant distributes a trip ticket. The toll opens at 6AM at which time vehicles begin to arrive at the rate of 8 vehicles per minute. After 20 minutes, the arrival flow rate declines to 2 vehicles per minute and it continues at that level for the remainder of the day. If the time required to distribute the trip ticket is 15 seconds, Determine the longest queue.

Mark the correct answer from the selection below.

☒ A 80

☐ B 160

☐ C 40

☐ D 20

- LONGEST QUEUE HAPPENS DURING THE FIRST 20 MINS
- QUEUE = ARRIVAL - DEPARTURE
 $QUEUE = 8(20) - 4(20)$
 $QUEUE = 80 \text{ VEH}$ //

LONGEST QUEUE = 80 VEH

Question No. 10 of 25

SITUATION. Vehicles arrive at the entrance of the new extension of NLEX. There is a single tollgate at which all vehicles must stop where a toll attendant distributes a trip ticket. The toll opens at 6AM at which time vehicles begin to arrive at the rate of 8 vehicles per minute. After 20 minutes, the arrival flow rate declines to 2 vehicles per minute and it continues at that level for the remainder of the day. If the time required to distribute the trip ticket is 15 seconds, Determine the total number of vehicles that have arrived and departed until no more queues exist.

Mark the correct answer from the selection below.

☒ A 240

☐ B 180

☐ C 120

☐ D 60

- t = 60 (QUEUE DISSIPATES)
- ARRIVAL = $8(20) + 2(60 - 20) = 240$ //
- DEPARTURE = $4(60) = 240$ //

240 VEH

Question No. 11 of 25

SITUATION. Scheduled maintenance will close two of the four westbound lanes of a freeway during one weekday from the period of 9:00 AM to 4:00 PM. The demand on the two lanes is as shown. If the capacity of four lanes with two lanes open is 2960 veh/hr, determine the following: Compute the time when the maximum queue occurs.

Time	Demand (vehicle/hour)
9 – 10 AM	4000
10 – 11 AM	3500
11 – 12 NN	2500
12 – 1 PM	2000
1 – 2 PM	2000
2 – 3 PM	2000
3 – 4 PM	2000

Mark the correct answer from the selection below.

☐ A 10 AM

☒ B 11 AM

☐ C 12 NN

☐ D 9 AM

Time	Demand (vehicle/hour)
9 – 10 AM	4000
10 – 11 AM	3500
11 – 12 NN	2500
12 – 1 PM	2000
1 – 2 PM	2000
2 – 3 PM	2000
3 – 4 PM	2000

COMMUNALATIVE DEMAND	SERVICE RATE	DEMAND - SERVICE RATE	COMMUNALATIVE SERVICE RATE	QUEUE
4,000	2960	2960	2960	1040
7,500	2960	5920	2960	1580
10,000	2960	8880	2960	1120
12,000	2960	11840	2960	160
14,000	2960	14800	2960	-800
16,000	2960	17760	2960	-1760
18,000	2960	20720	2960	-2720

MAX QUEUE AT 11 AM

Question No. 12 of 25

SITUATION. Scheduled maintenance will close two of the four westbound lanes of a freeway during one weekday from the period of 9:00 AM to 4:00 PM. The demand on the two lanes is as shown. If the capacity of four lanes with two lanes open is 2960 veh/hr, determine the following: Compute the maximum queue.

Mark the correct answer from the selection below.

☒ A 1580veh

☐ B 2720veh

☐ C 1760veh

☐ D 650veh

MAX QUEUE = 1580 VEH

Question No. 13 of 25

SITUATION. Scheduled maintenance will close two of the four westbound lanes of a freeway during one weekday from the period of 9:00 AM to 4:00 PM. The demand on the two lanes is as shown. If the capacity of four lanes with two lanes open is 2960 veh/hr, determine the following: Compute the maximum queue length in meters if one car is assumed to be 5 m long.

Mark the correct answer from the selection below.

☐ A 8000m

☒ B 3950m

☐ C 1975m

☐ D 2000m

- MAX QUEUE LENGTH = $\frac{1580 \text{ VEH} \left(\frac{5\text{m}}{\text{VEH}} \right)}{2 \text{ LANES}}$
 $MAX \text{ QUEUE LENGTH} = 3950 \text{ m}$ //

MAX QUEUE LENGTH = 3950 M

Question No. 14 of 25

SITUATION. A toll bridge carries 6000 veh/day. The current toll is \$3.50/veh. Studies have shown that for each increase in toll of 50 cents, the traffic volume will decrease by 500veh/day. It is desired to increase the toll to a point where revenue will be maximized. Determine the toll charge to maximize the revenues.

Mark the correct answer from the selection below.

☒ A 4.75

☐ B 4.50

☐ C 3.75

☐ D 6.85

COST = 3.5 + 0.5x

VOLUME = 6000 - 500x

REVENUE = COST x VOLUME

R = (3.5 + 0.5x)(6000 - 500x)

R = 21000 + 1250x - 250x² //

$\frac{dR}{dx} = 1250 - 500x$

0 = 1250 - 500x

x = 2.5 //

COST = 3.5 + 0.5x

COST = 3.5 + 0.5(2.5)

COST = \$4.75/VEH //

TOLL = \$ 4.75/ VEH

Question No. 15 of 25

SITUATION. A toll bridge carries 6000 veh/day. The current toll is \$3.50/veh. Studies have shown that for each increase in toll of 50 cents, the traffic volume will decrease by 500veh/day. It is desired to increase the toll to a point where revenue will be maximized. Determine the traffic in veh/day after toll increase.

Mark the correct answer from the selection below.

☐ A 2550

☐ B 6700

☒ C 4750

☐ D 4500

VOLUME = 6000 - 500x

VOLUME = 6000 - 500(2.5)

VOLUME = 4750 VEH //

VOLUME = 4750 VEH/DAY

Question No. 16 of 25

SITUATION. A toll bridge carries 6000 veh/day. The current toll is \$3.50/veh. Studies have shown that for each increase in toll of 50 cents, the traffic volume will decrease by 500veh/day. It is desired to increase the toll to a point where revenue will be maximized. Determine the total revenue with the new toll.

Mark the correct answer from the selection below.

☐ A 2,562.50

☐ B 22,652.50

☐ C 25,262.50

☒ D 22,562.50

REVENUE = COST x VOLUME

REVENUE = 4.75 x 4750

REVENUE = \$ 22,562.50 //

REVENUE = \$ 22,562.50

Question No. 17 of 25

SITUATION. Using the data given below solve for the following: Determine the peak hour volume.

Time	Volume
6:00 – 6:15	375
6:15 – 6:30	380
6:30 – 6:45	412
6:40 – 7:00	390

Mark the correct answer from the selection below.

☒ A 1557

☐ B 1648

☐ C 1500

☐ D 1345

PHV = 375 + 380 + 412 + 390

PHV = 1557 //

PHV = 1557

Question No. 18 of 25

SITUATION. Using the data given below solve for the following: Determine the peak hour factor.

Mark the correct answer from the selection below.

☐ A 0.924

☐ B 1.06

☒ C 0.945

☐ D 0.954

$PHF = \frac{PHV}{4(V_{15})} = \frac{1557}{4(412)}$

PHF = 0.945 //

PHF = 0.945

Question No. 19 of 25

SITUATION. Using the data given below solve for the following: Determine the design hourly volume.

Mark the correct answer from the selection below.

☐ A 1225

☐ B 1545

☒ C 1648

☐ D 1234

$DHV = \frac{PHV}{PHF} = \frac{1557}{0.945}$

DHV = 1648 //

DHV = 1648

Question No. 20 of 25

The accident rates for 100 million vehicle miles of travel caused by people attempting to pass a heavily traffic 2 lane rural highway is 6.0. The length of the road is 10 miles with an ADT of 36000. Determine the estimated yearly reduction in total crashes if the crash reduction factor is 0.25.

Mark the correct answer from the selection below.

☐ A 1

☒ B 2

☐ C 3

☐ D 4

- $R = 6.0$
- $L = 10 \text{ MILES}$
- $ADT = 36,000$

$$R = \frac{A(100,000,000)}{ADT(N)(365L)}$$
$$6 = \frac{A(100,000,000)}{ADT(1)(365)(10)}$$
$$A = 7.88 \approx 8 \text{ CRASHES} //$$

- $YEARLY \text{ REDUCTION} = 8(0.25)$
 $YEARLY \text{ REDUCTION} = 2 \text{ CRASHES / YEAR} //$

2 CRASHES / YEAR

Question No. 21 of 25

The mathematical model $N = 0.4x^2 - 36x + 1000$ approximates the number of accidents, N, per 50 million miles driven, for drivers who are x years old. The formula applies to drivers' ages 15 through 70 inclusive. Determine the number of accidents per 50 million miles driven for 20-year-old drivers.

Mark the correct answer from the selection below.

☐ A 250

☒ C 440

☐ B 450

☐ D 404

- $N = 0.4x^2 - 36x + 1000 ; 15 \leq x \leq 70$
 $N = 0.4(20)^2 - 36(20) + 1000$
 $N = 440 \text{ ACCIDENTS} //$

440 ACCIDENTS

Question No. 22 of 25

Based on the record of road accidents, find the number of fatal accidents in 1996 if the severity ratio is 0.24863.

Year	Property Damage	Injury	Fatal
1992	205	56	2
1993	178	48	3
1994	152	41	3
1995	190	60	5
1996	236	88	x

$\geq 961 \quad \geq 213 \quad \geq 13+x$

Mark the correct answer from the selection below.

☐ A 11

☒ B 12

☐ C 13

☐ D 14

- $SEVERITY \text{ RATIO} = \frac{f+i}{PD+i+f}$
 $0.24863 = \frac{(13+x) + 293}{961 + 293 + (13+x)}$
 $X = 11.997 \approx 12 //$

12 FATAL ACCIDENTS

Question No. 23 of 25

The projected AADT of a proposed facility is 33,000 veh/day. If the proportion of AADT in the design hour is 16 percent and the peak-hour directional distribution is 65:35. Assume that the fhv, and fp of the proposed facility are 0.925, and 1.0, respectively, the maximum service flow rate for the facility to provide a LOS of 1,500 veh/h/in. The number of lanes required will be

Mark the correct answer from the selection below.

☐ A 4

☒ B 3

☐ C 2

☐ D 1

- fhv** (Heavy Vehicle Adjustment Factor) = A factor used to reduce the service rate to account for slower and longer heavy vehicles in the traffic stream
- fp** (Driver Familiarity Adjustment Factor) = A factor that adjusts the service rate based on how familiar road users are with the roadway

- $AADT = 33,000$
- $K = 0.16$
- $D = 0.65$
- $DDHV = K(D)(AADT)$
 $DDHV = 0.16(0.65)(33,000)$
 $DDHV = 3432 //$

- $N = \frac{DEMAND}{CAPACITY \text{ PER LANE}} = \frac{3432 \text{ VEH/HR}}{1500 \frac{\text{VEH}}{\text{HR} \cdot \text{LANE}} (0.925)(1.0)}$
 $N = 2.47 \approx 3 \text{ LANES} //$

3 LANES

Question No. 24 of 25

Consider that 9,100 vehicles were observed during a seven consecutive days count. Assuming the monthly factor is 1.14. Estimate the AADT.

Mark the correct answer from the selection below.

☐ A 7983

☒ B 1482

☐ C 10,374

☐ D 10,743

- $MEF = 1.4$
- $V_{WEEK} = 9100$

- $MEF = \frac{AADT}{ADT \text{ FOR THE MONTH}} ; 1.14 = \frac{AADT}{9100/7}$
 $AADT = 1482 \text{ VEH/DAY} //$

AADT = 1482 VEH/DAY

Question No. 25 of 25

Suppose the hourly volume in east- and west-bound directions of a highway are 1,300 and 2,200 vph during the peak hour, respectively. Solve for the D-factor.

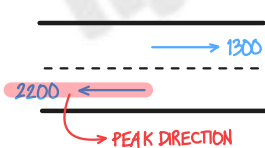
Mark the correct answer from the selection below.

☒ A 0.63

☐ B 0.59

☐ C 0.37

☐ D 0.92



- $D\text{-FACTOR} = \frac{2200}{2200 + 1300}$
 $D\text{-FACTOR} = 0.63 //$

D-FACTOR = 0.63